Volume 25 Issue 04, 2022 ISSN: 1005-3026 https://dbdxxb.cn/ Original Research Paper

MATHEMATICAL MODELING-BASED INTELLIGENCE VIDEO SURVEILLANCE SYSTEM FOR PREVENTING CRIMES OCCURRING AT ATM PREMISES

R.Ganapathyraja[1] and S.P. Balamurugan[2]

[1.]R.Ganapathyraja ,Deparment of Computer & Information Science,Annamalai University, Chidambaram, TamilNadu, India, r.ganapathyraja@gmail.com

[2].S.P. Balamurugan,Department of Computer & Information Science,Annamalai University, Chidambaram, TamilNadu, India, spbcdm@gmail.com

ABSTRACT

In recent years, ATM attacks have grown owing to flaws in the existing security systems. For this reason, many ATM premises have video surveillance systems installed to monitor crime. Nevertheless, it is extremely difficult for security officers in 24x7 days monitor in real-time. After an incident, security officers must manually search the incident videos from a huge collection, and the system will never detect and warn of criminal activities. This paper proposes the algorithms based on mathematical model for intelligent video surveillance systems to prevent the occurrence of criminal activities at ATM premises. There are two algorithms developed that address the two most critical issues facing ATM security services: ATM cash robbery detection and machine steal detection are based on frame differences and contour-based Approaches. Proposed algorithms are proven to provide accurate results with less time and less computational cost through excellent performance.

KEYWORDS: ATM, Cash Robbery, Machine Steal, Contour Area, Motion Detection, Object Tracking. Shape Analysis.

1. INTRODUCTION

In the modern Digital technology world, the Automatic Teller Machines (ATMs) is the most important and essential in real-time global banking service centre to the provide accessing the public 24/7 services for cash withdrawal and deposit[1].However, ATM premises are prone to crime when people do not access them in the middle of the night and a security guard to monitor the crime 24 hours is very difficult, some locations they are also attacked. Hence, CCTV surveillance cameras are installed at all ATM premises to prevent crime[2]. While at the same time, despite the presence of CCTV security systems on ATM premises, it has been reported in the news media that ATM crimes have increased in recent years such as money robbery, attacks on the security camera, and stealing the ATM as shown in Figure 1. Worldwide developed countries also fail the security system in ATM threats has been reported in news [3],[4]. The reason is CCTV surveillance video cameras are used only to record the real incident in thousands of video stream. In reality, it is a very tedious task round the clock as security officials have to manually monitor all the real-time footage from a centralized server room [5]. Thus most anomaly activities miss the video surveillance. After the crime, the footage is used only as forensic evidence for the investigation [6]. This traditional video surveillance does not

Submitted: 29/11/2022 **Accepted**: 17/12/2022

help much to prevent the crime at the time[7]. Therefore, this passive surveillance should be converted into an

a b c

Figure 1. ATM crimes: (a) Cash Robbery (b) Damage the Machine (c) Stealing the ATM

Figure 1. ATM crimes: (a) Cash Robbery (b) Damage the Machine (c) Stealing the ATM
integrated intelligent surveillance system for real-time live detection of ATM crimes using surveillance CCTV cameras[8]. Video analysis and computer vision are essential components of intelligent video surveillance systems (IVSS)[9].

This paper proposes a simplified efficient algorithm for designing a new mathematical model for intelligent video surveillance systems integrated with computer vision and image processing techniques to automatically detect ATM crimes from real-time visual or video feeds and trigger alarm sounds to prevent the crime. The two key issues of ATM crime discuss that are Money Robbery in ATM and Stealing the ATM machine. Novel solutions are proposed to rapidly detect and prevent the above ATM crime with low computationally cost and less execution time. The remaining contents of the paper are divided into four sections as follows: Section 2 presents the literature survey of related works. Section 3 expresses the background of the ATM security system and threats. Section 4 explains the solution for the existing issues through the proposed system. Section 5 shows the experimental result and discussion. Finally the conclusion and future work are given in Section 6.

2. LITERATURE SURVEY

The literature survey conducted to collect the benchmark video dataset associated with ATM crime activities found that there is insufficient information on any web portal. Only It was found that multiple videos related to ATM crime activities mainly concern to unusual events are available on YouTube[6].The proposed method requires normal and abnormal tested video datasets. The research is conducted using datasets from YouTube videos and Emmanu Varghese's own data[10].

There are several earlier works attempted to enhance the security of ATMs through image processing techniques and other methodology. Vikas Tripathi et al.[11]proposed Human Action Recognition(HAR) descriptor extraction technique uses HOG and the Random Forest classification technique to identify normal and abnormal events in ATM booth. Rupesh Mandal et al.[12]proposed a system to detect ATM theft using image processing and machine learning techniques. Based on a canny edge detector and a pre-trained burglary pattern matching method, theft is detected by tracking a moving object in a video frame. Emmanu Varghese et al.[10]developed an algorithm for anomaly activities detected in defined areas in ATM. The author has created his own video dataset which is trained and tested to use the proposed method.

The algorithm has two phases training and testing. Motion detection techniques and statistical methods are used to detect anomaly events in the testing videos. Wai-Kong Lee et al.[1]proposed an Archcam expert system used image processing techniques for detect suspicious behavior at ATM sites. A pair of algorithms was developed for an embedded system to detect two categories of suspicious activities. The first case is squatting and climbing in front of the ATM to rob the cash in the machine. Another case is attacking and removing ATMs from a site with a belt-shaped object then breaking it and looting the cash.

3. BACKGROUD

In recent years media reports state that ATM-related attacks and real-time surveillance cameras have not detected criminal activities during the time of incidents[5]. These challenging issues are faced by RBI regularly[1]. They motivated the development of an efficient algorithm integrated into computer vision security cameras for preventing ATM crimes.

3.1 ATM

The Automated Teller Machine (ATM) is a computerized machine is designed to facility the financial & non-financial transactions accessing without visiting the bank branch in real-time service to customers[13]. It is helps Banking cash-based transaction works are reduced, and banks earn more profit (any time deposit, debit card, passbook entry etc.). While customers can be process the transactions at any time and from anywhere. The ATM site is having a small size room environment. In which mostly machines are installed in the corner of the room. The room width, length and machine locations are important features of the research works[6].

3.2 Security Camera

ATMs usually have video surveillance cameras installed to monitor the environment for criminal activity prevention. ATMs usually have video surveillance cameras installed to monitor the environment for criminal activity prevention [1]. It is more crucial to install security cameras in the correct location and position on the site. i.e., back side top position of the machine to capture the human entering the ATM site, and also the camera should be mounted in such a way that it focuses the entrance of the room door. The routine primary work is the storage of ATM surveillance data. If any criminal activities happened the footage is used to prove the crime in the cases [14]. Therefore, the video footage is retained on the centralized server for a minimum of seven days to a maximum of ninety days.

3.3 Threats in ATM

A review of the research papers revealed that most researchers consider certain activities at ATM premises to be suspicious events. They are follows:

i. Suspected Person covers their faces with hats, helmets, masks, etc.

ii. Tamper the security camera such as hiding thru spray, hitting damage with a hard object, and changing the focus.

iii. Broken into an ATM machine on site and looting the cash from the machine.

iv. Stealing the ATM machine at site, then shift to another place and then breaking the machine and rob the cash.

v. When a person enters the ATM, he/she is followed, assaulted, and robbed of his belongings and money.

This article examines two major suspected threat issues from the mentioned above and the solutions are described in the next section.

4. SUSPICIOUS ACTIVITIES PREVENTION METHODOLOGY

This proposed method addresses the two major ATM threat issues are1. Cash Robbery and 2. Machine Steal. The objective of these criminal activities aims to damage the ATM and then rob the cash inside the machine. Hence to construct the rules in ATM premises for human behaviour are normal events and abnormal activities[15].

In the first issue (sect. 4.1) Cash Robbery Detection: These criminal activities aim to damage the lower part of the cash storage space in the machine and rob the money. ATM users have no permission to access the lower part of machine. Hence human activities are classified as normal activity: A person should enter the ATM room, move towards the ATM and stand in front of it to use and then leave the room. A key behaviour of the person must be standing position in the room until the process completed. While abnormal activities: A person enters the ATM room, moves behind the machine, and sits in front of the machine, bends, climbs, jumps and crouch down[16].

In the second issue (sect.4.2) Machine (ATM) Steal Detection: The goal of this crime is to steal the machine from ATM premises and take it to a secluded place, where it will be broken and the cash

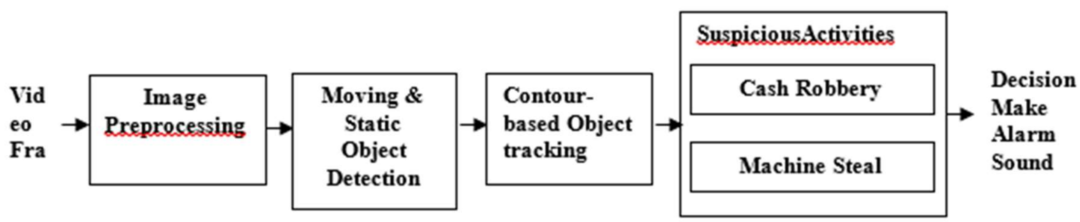


Figure 2. Block diagram of Proposed Model

stolen. This case normal activity: In the ATM room, the machine is fixed in the corner or centre of the place. That does not movable in any situation. Abnormal activity: Machine area is changed and shape is changed.

For the solution of the above issue, an effective algorithm has been implemented for preventing ATM crimes by utilizing image processing techniques for object detection and contour-based tracking as shown in Figure 2.

4.1 ATM Cash Robbery Detection

The first objective is, Human Shape from the surveillance camera's point of view; usually, the person has to walk or stand in the room. While during the human activities (normal or abnormal) in the ATM site person's vertical position shape is tracked and analyzed[17]. These shape key points are extracted using contour features[18]. These key points are connected to create the mathematical model based on vertical and horizontal lines. The height and width of the human shape are computed based on these model, and then the aspect ratio is used to analyze the human shape change.[19].

4.1.1 Image Preprocessing

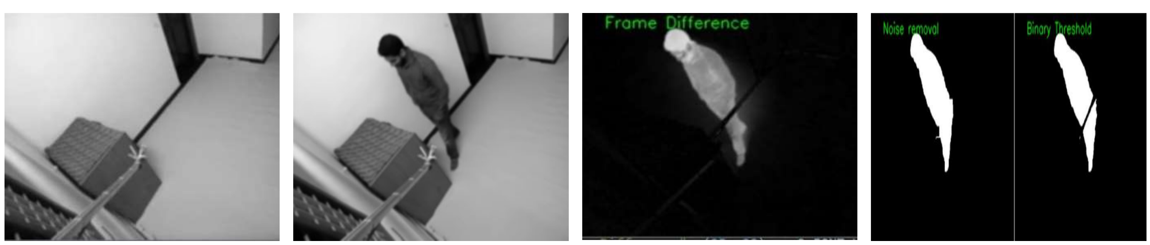
The primary stage of pre-processing in this method, acquired the video data from the surveillance camera or video feeds. These RGB videos are processed to image frames and then converted into grey scale frames. Intensity enhancement and illumination noises are reduced in the frames using Histogram Equalization (HE). After that image frames are smoothening using the Gaussian blur method[5].

4.1.2 Moving and Standing Human Detection

These frames contain the foreground and background scenes, the foreground segmentation is the key process of object detection methods that extract foreground objects and remove background scene from video frames[20].The proposed method requires both foreground moving and static objects detection in the frames. In this situation, the background subtraction method detects only moving objects while foreground non-movement objects are absorbed into the background. Hence it is not suitable for static object detection[21]. Therefore, this algorithm to uses the frame Difference method (FD)[22] for detecting the static and moving objects in the scene by using the formula as follows:

$$FD(x,y) = \begin{cases} 1, \left| f_k(x,y) - f_{k-1}(x,y) \right| \geq T \\ 0, \left| f_k(x,y) - f_{k-1}(x,y) \right| < T \end{cases}$$

Where, k(x, y) is reference frame (Figure 3 (a)), k-1(x,y) is current captured frame (Figure 3(b)) and T is the threshold. Generate the background model for the reference frame as the first step[23].The static or moving foreground object region is separated from the background scene using the frame difference method (Figure 3(c)).The frame difference image is converted into a binary image and segments the region of interest (ROI) objects using binary threshold techniques. Finally, remove the noise in the binary frame applied morphological operation Dilation and then followed by Erosion as shown in Figure 3(d).



(a) (b) (c) (d)

Figure 3. (a) Reference frame (b) current frame (c) foreground segment frame (d) ROI Object noises removed in the binary image frame.

Figure 3. (a) Reference frame (b) current frame (c) foreground segment frame (d) ROI Object noises removed in the binary image frame.

4.1.3. Contour-based Object Tracking

Contours and boundaries are very critical information for object representation and tracking [24].Object tracking is the vital role of video surveillance in the trajectory position and orientation of objects [25]] in each video frame. Segmented object contour features image moments (Equation 2) and Contour Area(Equation 3)[26] are important of this proposed method. Hence Contour-based object tracking algorithms [27] are used to find the shape of contour in the segmented objects afterwards extract the height and width of the contour shape.

$$M_{ij} = \sum_x \sum_y x^i y^j I(x,y) \tag{2}$$

$$CA = \sum_{x=0}^{w} \sum_{y=0}^{h} f(x,y) \tag{3}$$

In Equation 2. x and y denotes the row and column of pixel position and the pixel intensity of current location is I(x, y). Equation 3. w and h represents the contour boundaries width and height. X and Y represent the pixel location.

4.1.4. Human Shape measurement and Ratio Analysis

Foreground detected human object are defined by three different bounding points, which are top left, right, and bottom right coordinates. After establishing a connection between the points, height and width distance are calculated based on the vertical and horizontal lines by using Equation 4 as shown in Figure 4.

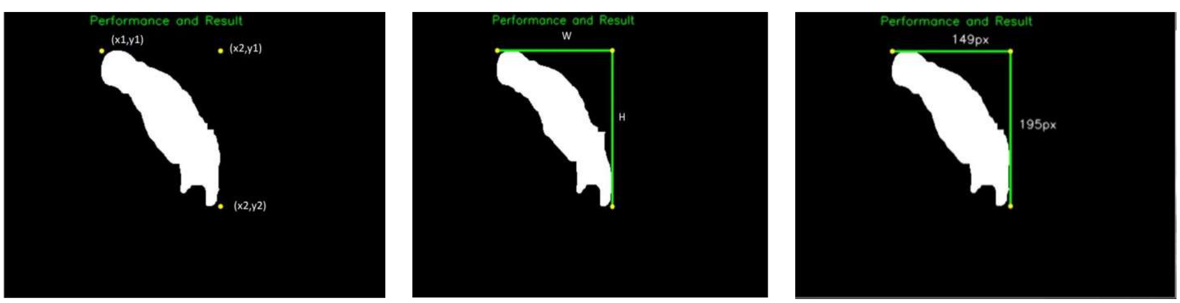


Figure 4. Human shape bounding points and measurement of hieght and width

Figure 4. Human shape bounding points and measurement of hieght and width

$$CH = \sqrt{(X_2 - X_2)^2 + (Y_2 - Y_1)^2}$$
$$CW = \sqrt{(X_2 - X_1)^2 + (Y_1 - Y_1)^2} \tag{4}$$

Where CH denotes changes of human height and CW denotes changes of human width. The parameters of horizontal and vertical lines are estimated from the coordinate point's human head to foot. The proposed model to analysis the human pose changes standing to sitting down or squatting down based on the vertical and horizontal lines ratio of the distance. It is necessary to compute the height-to-width aspect ratio as follow:

$$AR = \frac{\Delta CH}{\Delta CW} \quad (5)$$

Human activities can be classified as normal (standing or walking) or abnormal (sitting or crouching down) using the aspect ratio (AR) [28]. If the AR is less than the prescribed threshold, the actions are classified as abnormal; otherwise, they are classified as normal. The pseudo-code1 of the abnormal activities detection for ATM cash robbery is as follows:
Pseudo-code of the proposed method1

```
Input  :  Human contour shape
Output:  Abnormal activities detected and Make Alert sound

COMPUTE Contour Area CA (using Eq.3)
COMPUTE horizontal(CW) and vertical(CH) line(using Eq.4)
COMPUTE Aspect Raito AR (using Eq.5)

SET Framecount = 0
IF CA > Threshold
    Motion Detected
    IF  AR < Threshold
        Abnormal Activities Detected
        SET status Abnormal
        Framecount increment by one
    ELSE
        SET status Normal
        RESET Framecount = 0
   EDNIF
   IF Activities status is  Abnormal AND Framecount> 300
      Robbery confirmed and  Make Alert sound
   ENDIF
ELSE
   No Motion
 ENDIF
 END
```

In the above pseudo-code, if motion is detected in the camera view when the human (large ROI) enters the ATM premise the proposed algorithm starts the tracking process. The human shape analysis based on the human height width ratio (Equation 5). AR threshold reduce significantly when the user squats or sits. The state is set to abnormal and the frame counter is incremented when abnormal activities are detected, otherwise the state is set to normal and the frame counter is reset as shown in Figure 5. Finally, if the condition is abnormal and the frame count is higher than 300, it is confirmed to be an ATM robbery and an alert sound is triggered inside and outside the ATM premises.

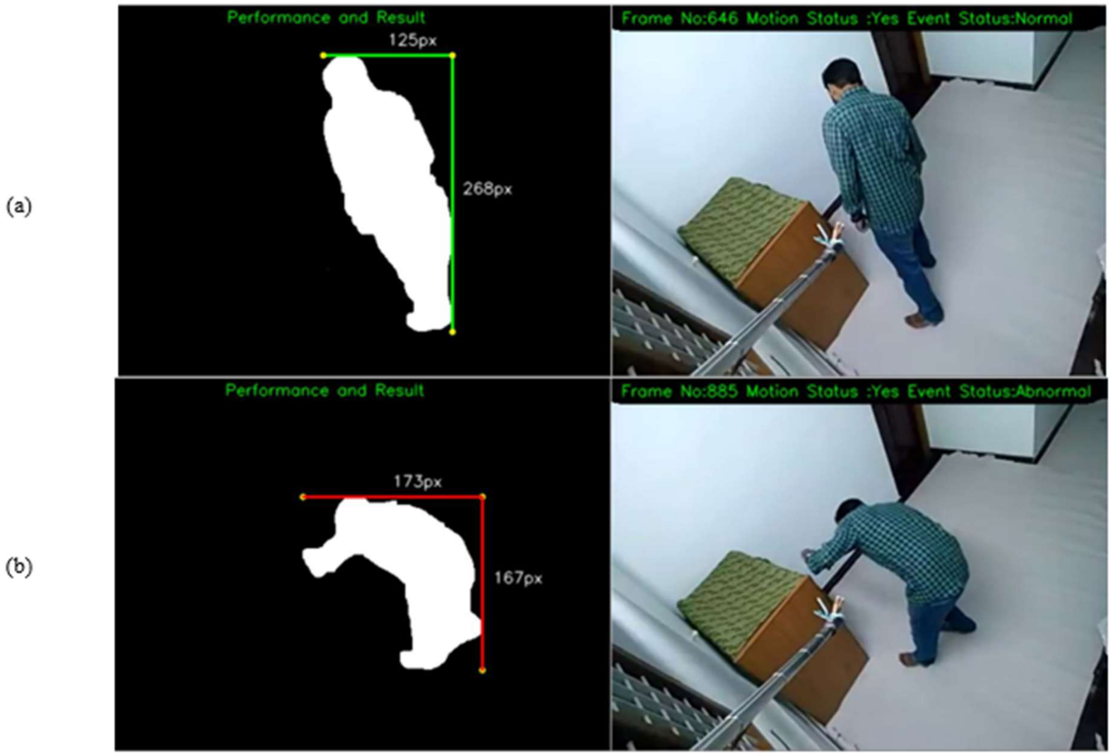


Figure 5. Human shape analysis: (a) Normal Activities(standing) (b) Abnormal Activities(crouch down)

4.2 Machine Steal Detection

The second objective of this proposed method is to monitor (capture) only the ATM region (ROI) and position by the surveillance camera. While the ATM continuously monitors frames containing the border region. If there is any change in the area compared to the pre-defined area ATM theft is detected.

4.2.1 Image Preprocessing

The same processes explained in section 4.1.1 are also applied here. Afterward mask canvas frames are created geometric mathematical model with the same dimensions as in the video frame. A bitwise AND operation and mask are used to generate the ROI of the polygon machine shape from the initial frame. The remaining other unwanted portions are masked as shown in the Figure 6(a).The silhouette of the machine shape is marked using polyline method in the masked canvas frame and current frame(see Figure 6(a,b)).

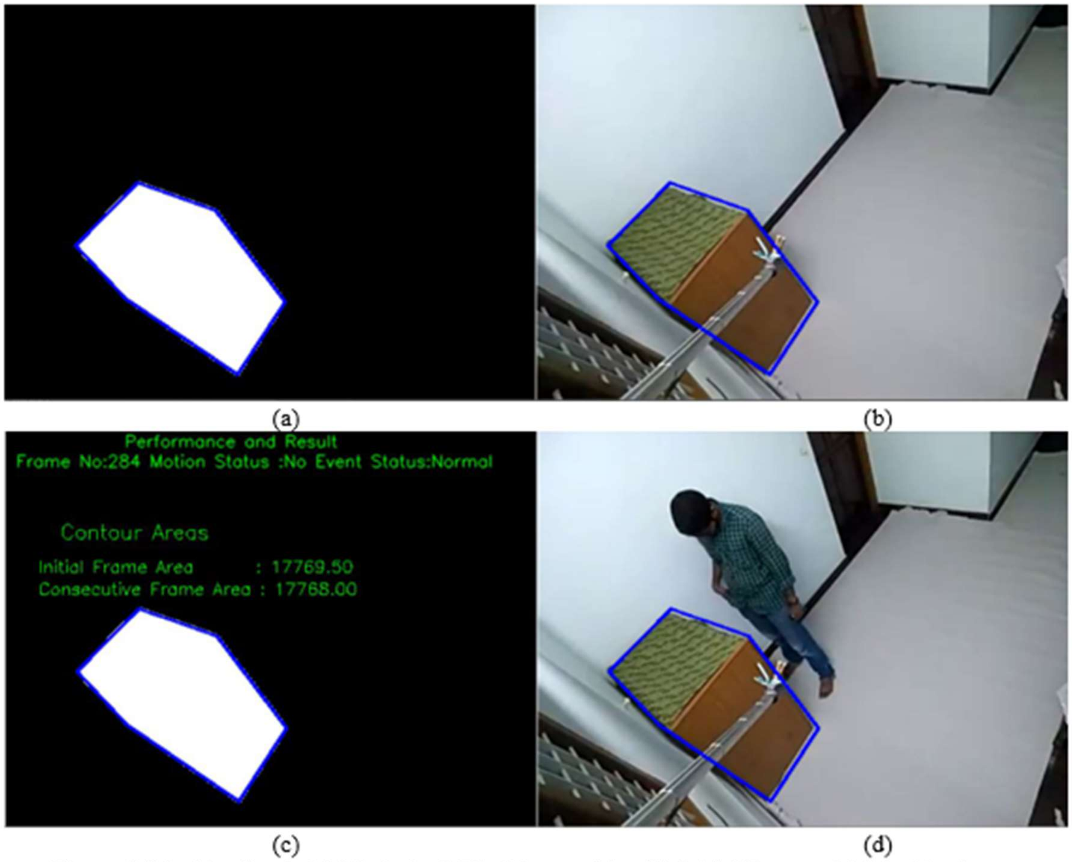


Figure 6. Machine Steal: (a) Mask the ROI of the machine (b) Initial Frame with Machine image (c) Contour area of the initial frame and consecutive frame (d) Haman enter the frame No motion status

4.2.2. Contour based Tracking Method

Contours are pixel-width and pixel-length segments, while boundaries are unbroken contour-based object shapes [29]. Contour boundaries are essential for representing objects and recognizing images [18].

A contour-based tracking method (section 4.1.3) computes the contour of an object based on its previous and next frames. Moreover, any changes in the contour location update the object's changes information. In this continuous process, the initial frame of the large contour area (Equation 2) of the object is first computed. The second calculates the contour area of the object in the next subsequent frames as shown in Figure 6(c).

4.2.3. Motion Detection

Motion detection[30] is identified in contour shape object using Frame difference (Equation1). If the motion is detected in the ROI of next subsequent frames then the contour area is calculated. If the pixel value is less than the predefined contour area pixels, some object is considered to be overlapping on the machine (i.e. placing a man's head or hand in the machine and covering it or any object like a helmet, bag etc.) If it is larger, some part of the contour shape is assumed to be deformed (i.e. damage the machine).

A normal activity is if the predefined contour area pixel value maintains the same values across successive frames. Otherwise any large changes (increase or decrease) in pixel values in consecutive frames are considered suspicious activity. And if these prolong, sound the alarm inside and outside the ATM premise. The below pseudo-code2 for abnormal activities detection of ATM steals.

Pseudo-code of the proposed method 2

```
Input : Masked contour shape object
Output: Abnormal activities detected and Make Alert sound

COMPUTE Contour Area CA (using Eq.3)
SET status Normal
SET Framecount = 0
SET ErrorArea = 1000
SET Actual_CA = CA(initial big contour)
IF (CA-ErrorArea)>Actual_CA or CA+ErrorArea) <Actual_CA
Abnormal Activities Detected& SET Motion YES
SET status Abnormal
Framecount increment by one
ELSE
SET Motion NO
SET status Normal
RESET Framecount = 0
EDNIF
IF Activities status is Abnormal AND Framecount> 300
Machine steal confirmed and Make Alert sound
ENDIF
END
```

5. EXPERIMENTAL RESULT AND DISCUSSION

The proposed system is implemented in Python 3.8 with the OpenCV 4.1.2 library and a 2.10 GHz Ryzen 5 3500U CPU and 8 GB of RAM. There is no public access to ATM crime-related testing video datasets. Therefore, Immanuel Varghese's own mock ATM setup video datasets and real ATM crime CCTV footages from YouTube are used in these experiments.

5.1 Experiment I

In this experiment for ATM cash robbery detection method used the Immanuel Varghese's own recorded mock video datasets [10]. This dataset contains nine different video clips from the ATM mock setup premise.

This proposed method detects both normal events based on green lines and abnormal events based on red lines in the test video because the performance analysis is based on accuracy. In this dataset, the events and activities in the testing videos listed in Table1.

Table 1. Testing video dataset performances

ATM site Events	Activities
Person walk or standing in the room	60 -Normal

Person crouch down or sit down inside the room or in front of the machine	13 -Abnormal

Figure 7 shows the algorithm detects of the normal and abnormal activities in the mock ATM test videos. The person enter the scene and access the machine as shown in Figure 7 (a) and (d), the algorithm detects these normal event activities(standing and walking). There may be two people in the room when the machine is used, but usually only one person uses it. Hence these are detected to be activities of normal event as seen in Figure 7(c). The objective of the algorithm is to detect the abnormal activities in the testing video. Figure 7(b),(e),(f) shows the abnormal events are happens in the videos.

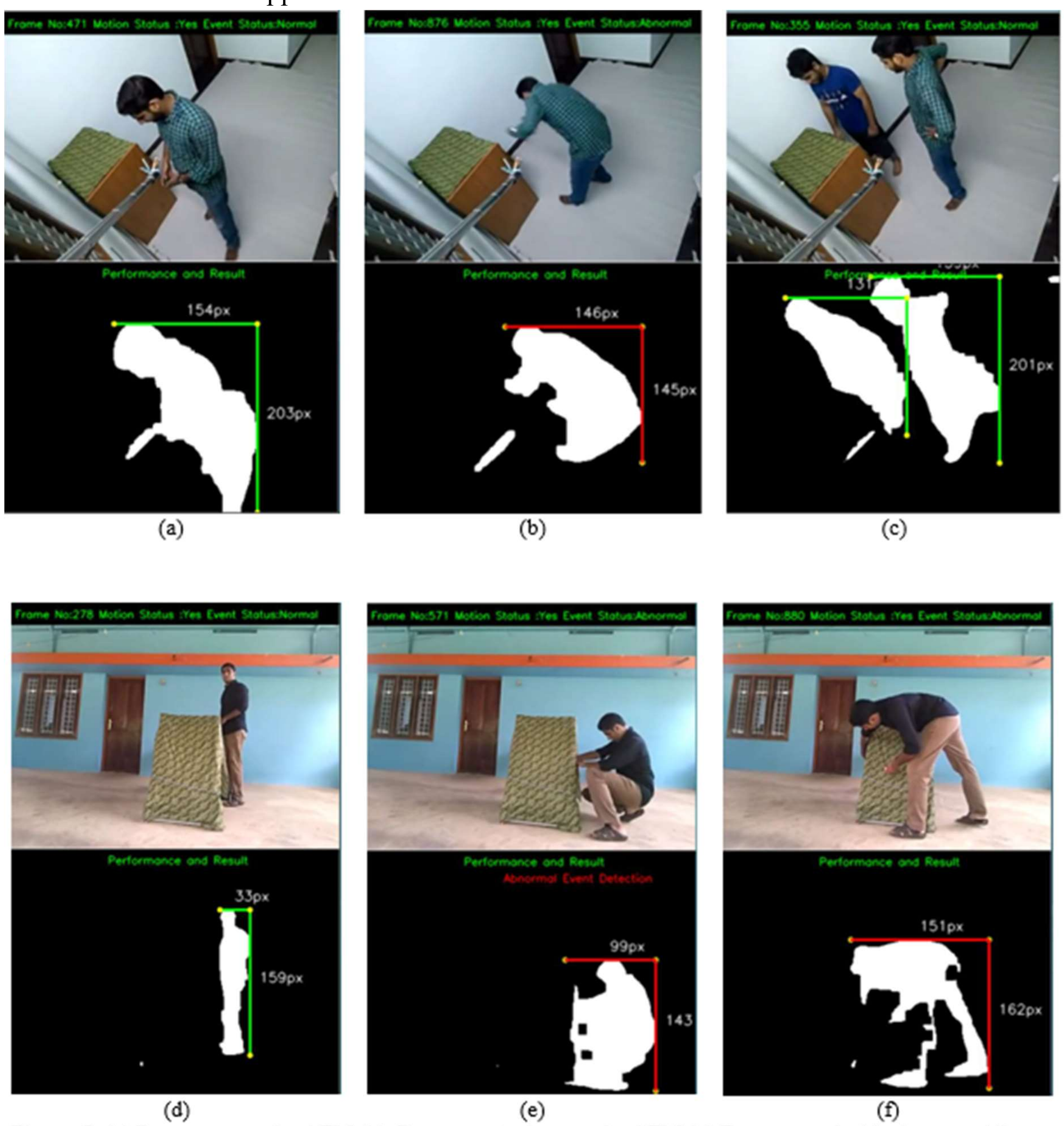


Figure 7. (a) Person access the ATM (b) Person try to damage the ATM (c) Two person inside the room (d) Person entery room (e) & (f) Person damage the machine

Table 2. Performances Accuracy of ATM cash Robbery Detection

Events	Abnormal Detection	Normal Detection	ACC ERR
Crouch/Sit Down	12	1	97.2%
Walk/Standing	1	59	2.7%

The performance measure based on events activities (Table 1). The proposed algorithm accurately detects 12 abnormal activities except one of crouch-down (Figure 7(b,f)) and sit-down (Figure 7(e)). One scenario was wrongly detected when a person is standing too close to the camera and the remaining normal function is 59 normal detections. The accuracy (ACC) of ATM cash robbery detection is 97.2% and the false alarm rate (ERR) is 2.7% presented in the Table 2.

5.2. Experiment II

In this experiment for Machine Steal detection method used the Immanuel Varghese's own recorded mock video datasets [10] and real time CCTV instanced scenario from YouTube.

This proposed method performance evaluated only based on the abnormal activity events in the ROI(ATM contour shape) of the video frames. The abnormal events are identified based on motion detection in the machine area as shown in Table 3.

Table 3.Testing video dataset performances

ATM site Events	Activities
Motion less in the machine area	Normal
Motion in the machine area	Abnormal

Fig. 8 shows that the algorithm detects the abnormal events based on the contour area computation of the clustered pixels. Only two video scenarios are used in the experiment. In video1, Figure 8(a) Person looks at the back of the machine and tries to damage the machine. In the situation, contour area computed is a slight change but there are no changes in the status. The person's head enters the machine area, so motion is detected, causing large changes in the contour area measurement. So this event is considered unusual activity as shown in Figure 8(b). In Video 2, the person enters the ATM room and operates the machine while resting their phone on top of it. In this case, the ROI of the contour area shows a slight change in computation due to the addition of a new object, but no change in position as shown in Figure 8(c).

The YouTube video scene, Figure 8(d) shows that there is no motion detected in the marked machine portion contour area. The Machine is damage by JCB, the damaged portion marked as red color and also contour area is measured by the damaged portion as shown in Figure 8(e). As shown in Figure 8(f), the machine is completely stolen from the room as indicated by the position.

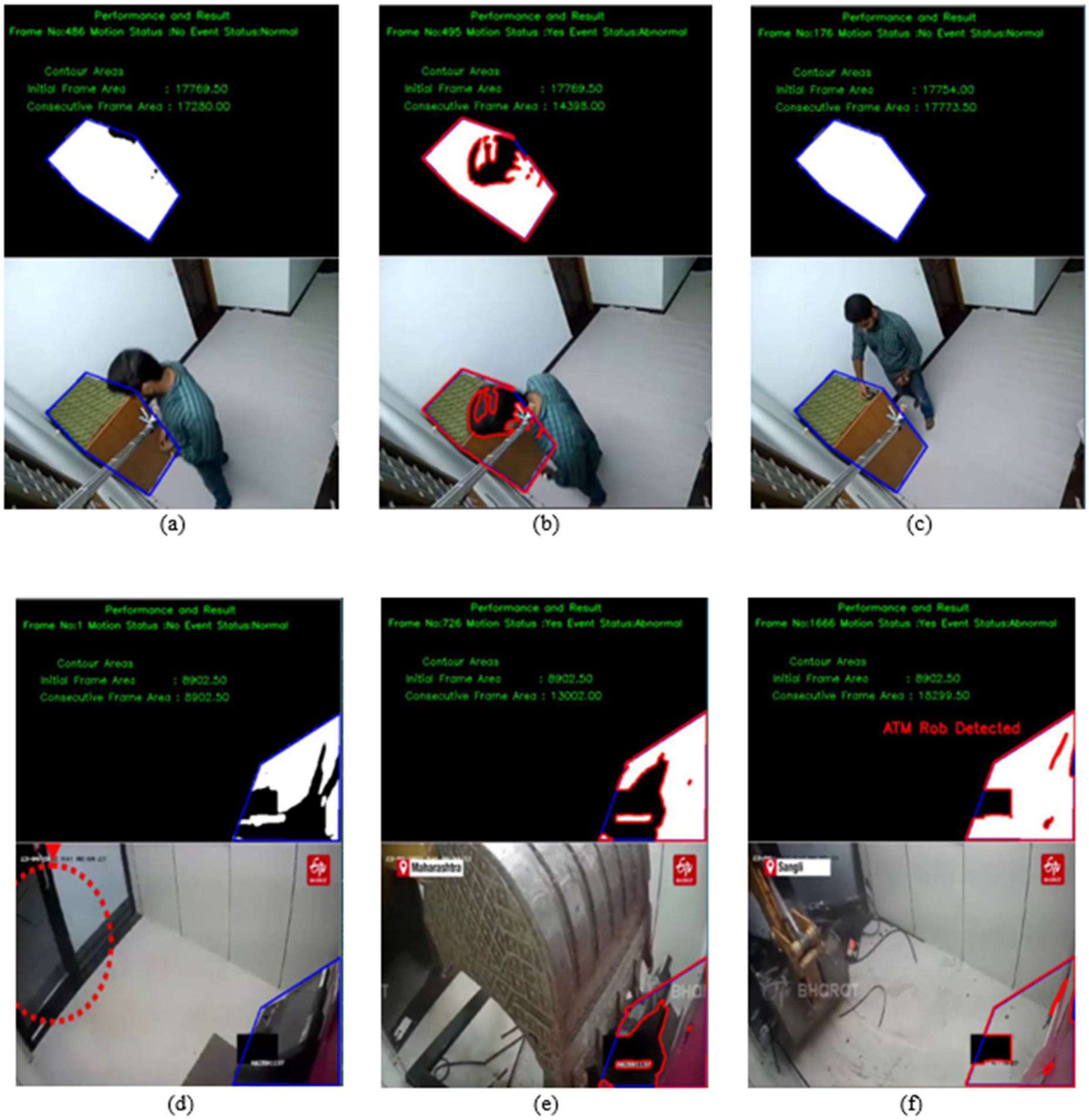


Figure 8. (a) Person move into Machine ROI (b) Person head part entried into the machine area (c) Person put the mobile on the machine area (d) Motionless machine area (e)JCB damage the machine (f) Machine is removed from the site.

Table 4 present the results of the performance computation using the quantitative analysis method. As a result of changes in illumination, reflection, and shadows, the machine contour area updates. Hence 15% errors are allowed to be avoided in this method as shown in Figure 8(a) and (b). All remaining video frames in the abnormal activities are accurately detected. As shown in Figure 8(b),(e),(f).

Table 4.Real quantitative and computation measure

Video	Frame#	Status	Real Quantitative measure	Computed Measure	Damage Detection Rate
V1	486	Normal	17769.50	17280.00	10%

	495	Abnormal	17769.50	14398.00	81%
V2	176	Normal	17754.00	17773.50	9%
YT V1	1	Normal	8902.50	8902.50	0%
	726	Abnormal	8902.50	13002.00	146%
	1666	Abnormal	8902.50	18299.50	205%

6. CONCLUSION AND FUTURE WORK

This paper proposed a simplified efficient algorithm based on mathematical model for an intelligent video surveillance system to detect suspicious activities in ATM premises for preventing crimes. In this proposed intelligent system, there are two algorithms are developed: 1) ATM cash robbery detection and 2) Machine Steal detection. These algorithms are used frame difference technique for motion detection. Also, contour-based object tracking and contour features are used for detecting abnormal activities. The proposed algorithm requires no training, the computation complexity is less and is more cost-effective than existing methods. The experimental results show that the proposed two algorithms are achieving good accuracy and fewer error rates in detecting various abnormal activities.

Even though these algorithms provide higher accuracy in ATM crime detection and prevention, the entire system will fail if the camera gets tampered with because the majority of ATM crimes are committed after tampering with the camera. Hence the scope of future work is to strengthen this intelligent system by preventing security camera attacks.

REFERENCES

[1] W. K. Lee, C. F. Leong, W. K. Lai, L. K. Leow, and T. H. Yap, “ArchCam: Real time expert system for suspicious behaviour detection in ATM site,” Expert Syst. Appl., vol. 109, pp. 12–24, 2018, doi: 10.1016/j.eswa.2018.05.014.

[2] A. Nurhopipah and A. Harjoko, “Motion Detection and Face Recognition For CCTV Surveillance System,” vol. 12, no. 2, pp. 107–118, doi: 10.22146/ijccs.18198,2018.

[3] Graczyk, M.: Masked men steal lobby ATMs from 5 Houston Marriott hotels. Daily Herald, Houston: (14 Dec 2017). http:// www.daily heral d.com/artic le/20171 214/news/ 31214 9823.
Accessed 17 Dec 2017.

[4] “Over Rs. 23 lakh cash stolen from two SBI ATM kiosks, India, https://timesofindia.indiatimes.com/city/hyderabad/over-rs-23l cash-stolen-from-two-sbi-atm-kiosks/articleshow/78502423.cms (2020). Accessed 06 October 2020.,” no. September, p. 78502423, 2020.

[5] T. Sikandar, K. Hawari, G. Mohammad, and F. Rabbi, “ATM crime detection using image processing integrated video surveillance : a systematic review,” Multimed. Syst., vol. 25, no. 3, pp. 229–251, doi: 10.1007/s00530-018-0599-4, 2019.

[6] S. Angadi and S. Nandyal, “Database Creation for Normal and Suspicious Behaviour Identification in ATM Video Surveillance,” 7th Int. Conf. Adv. Comput. Commun. Comput. Sci. 115 448–459 1, pp. 1–6, 2019.

[7] D. K. Singh, S. Paroothi, M. K. Rusia, and M. A. Ansari, "Human Crowd Detection for City Wide Surveillance," Procedia Comput. Sci., vol. 171, no. 2019, pp. 350–359,doi: 10.1016/j.procs.2020.04.036,2020.

[8] R. Ganapathyraja and S. P. Balamurugan, "An Extensive Review on Various Techniques for Suspicious Activities Detection in Intelligent Video Surveillance System," vol. 1, pp.1-6, 2021.

[9] H. Liu, S. Chen, and N. Kubota, "Intelligent video systems and analytics: A survey," IEEE Trans. Ind. Informatics, vol. 9, no. 3, pp. 1222–1233, doi: 10.1109/TII.2013.2255616,2013.

[10] E. Varghese, J. Mulerikkal, and A. Mathew, "Video Anomaly Detection in Confined Areas," 7th Int. Conf. Adv. Comput. Commun. Comput. Sci., vol. 115, pp. 448–459, 2,doi: 10.1016/j.procs.2017.09.104,2017.

[11] V. Tripathi, A. Mittal, D. Gangodkar, and V. Kanth, "Real time security framework for detecting abnormal events at ATM installations," J. Real-Time Image Process., vol. 1, doi: 10.1007/s11554-016-0573-3, 2016.

[12] R. Mandal, "Automatic Video surveillance for theft detection in ATM machines : An enhanced approach," no. August, 2016.

[13] R. Kayalvizhi, M. T. Kuil, and M. Saranya, "ANTI-THEFT ATM ROBBERY DETECTION USING BIG SURVEILLANCE VIDEO DATA," vol. 1, no. 1, pp. 1–4, 2019.

[14] S. Patil and K. Talele, "Suspicious movement detection and tracking based on color histogram," Proc. - 2015 Int. Conf. Commun. Inf. Comput. Technol. ICCICT 2015, doi: 10.1109/ICCICT.2015.7045698, 2015.

[15] A. Ben Mabrouk and E. Zagrouba, "Abnormal behavior recognition for intelligent video surveillance systems: A review," Expert Syst. Appl., vol. 91, pp. 480–491, doi: 10.1016/j.eswa.2017.09.029, 2018.

[16] S. Chaudhary, M. A. Khan, and C. Bhatnagar, "Multiple Anomalous Activity Detection in Videos," Procedia Comput. Sci., vol. 125, pp. 336–345, doi: 10.1016/j.procs.2017.12.045, 2018,.

[17] S. Li, V. H. Nguyen, M. Ma, C. Bin Jin, T. D. Do, and H. Kim, "A simplified nonlinear regression method for human height estimation in video surveillance," Eurasip J. Image Video Process., vol. 2015, no. 1, pp. 1–9, doi: 10.1186/s13640-015-0086-1,2015.

[18] R. J. Hemalatha, T. R. Thamizhvani, A. J. A. Dhivya, J. E. Joseph, B. Babu, and R. Chandrasekaran, "Active Contour Based Segmentation Techniques for Medical Image Analysis," Med. Biol. Image Anal., pp. 1–14, doi: 10.5772/intechopen.74576,2018.

[19] J. L. Chua, Y. C. Chang, and W. K. Lim, "A simple vision-based fall detection technique for indoor video surveillance," Signal, Image Video Process., vol. 9, no. 3, pp. 623–633, doi: 10.1007/s11760-013-0493-7, 2015.

[20] R. K. Tripathi, A. S. Jalal, and C. Bhatnagar, "A framework for abandoned object detection from video surveillance," 2013 4th Natl. Conf. Comput. Vision, Pattern Recognition, Image Process. Graph. NCVPRIPG 2013, doi: 10.1109/NCVPRIPG.2013.6776161, 2013.

[21] R. C. Joshi, M. Joshi, A. G. Singh, and S. Mathur, "Object detection, classification and tracking methods for video surveillance: A review," 2018 4th Int. Conf. Comput. Commun. Autom. ICCCA 2018, pp. 1–7, doi: 10.1109/CCAA.2018.8777708, 2018.

[22] Y. Zhang, X. Wang, and B. Qu, "Three-frame difference algorithm research based on mathematical morphology," Procedia Eng., vol. 29, pp. 2705–2709, doi: 10.1016/j.proeng.2012.01.376, 2012.

[23] T. T. Zin, P. Tin, H. Hama, and T. Toriu, "Unattended object intelligent analyzer for consumer video surveillance," IEEE Trans. Consum. Electron., vol. 57, no. 2, pp. 549–557, doi: 10.1109/TCE.2011.5955191, 2011.

[24] J. Seo, S. Chae, J. Shim, D. Kim, C. Cheong, and T. D. Han, "Fast contour-tracing algorithm based on a pixel-following method for image sensors," Sensors (Switzerland), vol. 16, no. 3, pp. 1–27, doi: 10.3390/s16030353, 2016.

[25] G. Mathur and M. Bundele, "Research on Intelligent Video Surveillance techniques for suspicious activity detection critical review," 2016 Int. Conf. Recent Adv. Innov. Eng. ICRAIE 2016, vol. 2016, pp. 1–8, doi: 10.1109/ICRAIE.2016.7939467, 2016.

[26] J. Howse, P. Joshi, and M. Beyeler, OpenCV: Computer Vision Projects with Python. 2016.

[27] H. Y. Cheng and J. N. Hwang, "Integrated video object tracking with applications in trajectory-based event detection," J. Vis. Commun. Image Represent., vol. 22, no. 7, pp. 673–685, doi: 10.1016/j.jvcir.2011.07.001,2011.

[28] K. L. Lu and E. T. H. Chu, "An image-based fall detection system for the elderly," Appl. Sci., vol. 8, no. 10, pp. 1–31, doi: 10.3390/app8101995,2018.

[29] A. Mondal, S. Ghosh, and A. Ghosh, "Efficient silhouette-based contour tracking using local information," Soft Comput , Springer,doi: 10.1007/s00500-014-1543-y,2014.

[30] Nishu Singla, "Motion Detection Based on Frame Difference Method," International Journal of Information & Computation Technology, Volume 4, Number 15, pp. 1559-1565,2014.